

The University of Chicago

VEGETATION AND SUBSTRATE
OF CRANBERRY GLADES
WEST VIRGINIA

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF BOTANY

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By

H. CLAYTON DARLINGTON

Reprinted from
THE BOTANICAL GAZETTE
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CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 551

H. CLAYTON DARLINGTON

(WITH SEVENTEEN FIGURES)

Introduction

In several parts of West Virginia there are small isolated areas of bog or peat-land ranging in elevation from 2500 to 3500 feet. The most important in size and peculiar vegetation are the Cranberry Glades in Pocahontas County. These occur in a level area of about 600 acres, at an elevation of 3375 feet, surrounded by hills ranging in elevation from 4000 to 4600 feet. Approximately 400 acres are covered with shrubs; about 80 acres with bog forest; and about 120 acres with sedges, mosses, and lichens. The latter 120 acres are popularly called "glade," four divisions of which are designated as Big Glade (approximately 60 acres), Flag Glade (28 acres), Long Glade (20 acres), and Round Glade (8 acres). Six different plant communities were recognized at the beginning of the study as worthy of investigation: bog forest, sedge-sphagnum, moss-lichen, sphagnum-cranberry-beaked rush, and two shrub communities.

The area lies in the southwestern part of Pocahontas County, about 20 miles west of Allegheny Mountain and the Virginia state line, and 9 miles west of Marlinton, the county seat of Pocahontas County (fig. 1). It is at the headwaters of Cranberry River, which flows through the bog. The area may be reached at present by turning off from Federal Route 219 at Millpoint and following the road up Stamping Creek to its head on Cranberry Mountain, the round trip to-

taling 12-15 miles. One then must walk 7 miles on a round trip from the top of Cranberry Mountain to the different parts of the bog.

The objects of the present investigation were: (a) to examine the geology of the region and the profile of the bog sediments with the hope of finding some ex-

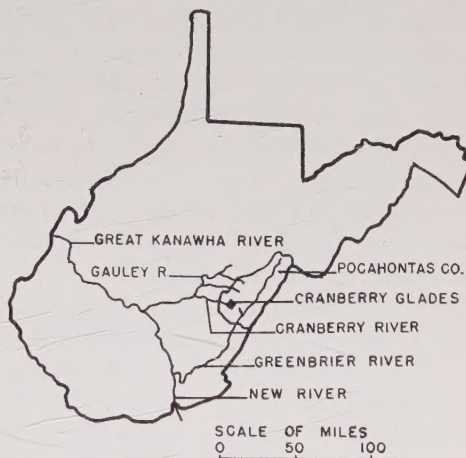


FIG. 1.—Location of Cranberry Glades, West Virginia.

planation for the formation of the level bog area; (b) to examine the layers and the pollen of the peat to shed some light on the past history of the vegetation of the region; (c) to study the various ecological factors and their influence in producing the present forest, shrub, sedge, and moss communities; and (d) to observe successional trends and try to determine the probable future of the area. The study has extended over a period of 12 years. Previous to 1941 only two or

three trips were made to the bog each year, but beginning with April, 1941, full time was devoted to the work until November of that year.

BROOKS (1, 2) listed some of the common plants, birds, and mammals of Cranberry Glades and estimated the approximate acreage of the different glades. He noted the importance of the area on water flow. SHELDON (11) collected and identified many species of fungi from this region. STRAUSBAUGH (12) discussed some of the bog species and also some of the rare plants of the area, such as *Cornus canadensis*.¹

Climatic

General climatic conditions in Pocahontas County can be divided into two classes, the highland climate and the low valley climate. The valleys have an elevation of 2100-2400 feet, while the highlands reach 3000-4600 feet. Winters are severe in both but are more severe in the highlands. Summers are cool, with the maximum day temperature in July rarely above 88° F. in the valleys or 80° F. in the highlands. Night temperatures may drop as low as 55° F. in Cranberry Glades in July.

While there is no complete record of climatic factors in the highlands, data have been kept for 30 years by S. L. BROWN at Marlinton (2125 feet). Temperatures throughout this paper are given in Fahrenheit and precipitation in inches. These records show a 30-year mean air temperature of 48°, with means of 67.6° and 27.7° for July and January. The maximum mean for July was 71.2° in 1898; the minimum mean, 62.3° in 1920. The highest mean for January was 34.4° in 1913; the lowest was 16° in 1918. There is no record available for the ab-

solute maximum and minimum during this 30-year period; however, in Cranberry Glades during the summer of 1941 the maximum recorded was 82° on July 22.

The 30-year mean in precipitation is 47.28 inches. July has the highest monthly mean (5.31 inches); November the lowest (2.93 inches). The highest annual rainfall recorded was 63.62 in 1918, and the lowest was 39.54 in 1912. The rainfall is fairly evenly distributed through the months of the year, September, October, and November having the lowest monthly values and June, July, and August the highest. This is favorable to plant growth. In snowfall the 30-year mean is 31.5 inches, with 9.5 for January, 9.2 for February, 5.8 for March, 1.2 for April, a trace for May, 0.6 for October, 1.6 for November, and 6.3 for December. No snow has been reported for June, July, August, and September. The maximum annual fall was 48.5 inches for 1916; the minimum annual was 11.5 for 1913.

Mean length of the frost-free period for the 30-year period is 146 days, May 15 to October 8. The maximum was in 1919, April 19 to October 20 (183 days), while the minimum was in 1913, June 10 to September 23 (104 days). For the Cranberry Glades region it would be a close approximation to put the mean annual temperature at 42°, the mean annual rainfall at 51 inches, the mean annual snowfall at 40 inches, and the mean frost-free period at 140 days. Although not present to record the temperature, the writer has satisfactory evidence in the appearance of the plants that in 1941 there was frost on May 15 and October 2, a frost-free period of 140 days.

Physiography and geology

The area is in the Allegheny Plateau subdivision of the Appalachian Province.

¹ With the exception of lichens and mosses, the nomenclature used is that of GRAY'S New manual of botany, 7th ed.

The rocks exposed are sandstones and shales, which, with the limestone beneath, were deposited in a vast inland

long and $\frac{1}{4}$ -1 mile wide. It lies at an elevation of a little less than 3400 feet at the upper or eastern end and 3350 feet

TABLE 1
GENERAL COLUMNAR SECTION OF ROCKS EXPOSED IN CRANBERRY GLADES AREA
OR LYING BENEATH IT

Era	Period	Series	Group	Thickness (feet)	Description
Quaternary	Recent			?	Unconsolidated clays and gravel
	Pleistocene			?	Unconsolidated clays and gravel
Paleozoic	Upper Carboniferous or Pennsylvanian	Pottsville	Kanawha (part)	130	Sandstones, shales, coals
			New River	500	Massive sandstones, hard dark shales, coals
			Bluestone	75-200	Vari-colored soft shales and sandstones
			Princeton conglomerate	50-70	Massive gray and brown sandstones with pebbles
	Lower Carboniferous or Mississippian	Mauch Chunk	Hinton	500-700	White weathering sandstones, variegated shales (soft)
			Bluefield	550-800	Variegated shales, sandstones, and limestone
		Greenbrier		220-600	Limestone of various colors (gray, blue, light gray)
					Red and purple shales
		Maccrady		20-50	
		Pocono		60-600	Sandstones and shales

sea during Mississippian and Pennsylvanian time and were uplifted at the close of the Permian (table 1). The region of greatest uplift was farther east, causing all strata in this area to dip to the west.

During Cretaceous or Jura-Cretaceous time the Allegheny Plateau was eroded by water action to an almost perfect base level, the Schooley peneplain. Another uplift at the close of the Cretaceous was followed by peneplanation in the less resistant areas to the Harrisburg peneplain in Tertiary time. Black Mountain, with an elevation of 4600 feet, and other hills around the bog area are remnants of the Schooley peneplain. Still another uplift occurred at the close of the Tertiary, resulting in further dissection and erosion.

The level bog area, apparently a part of the Harrisburg peneplain, is 3 miles

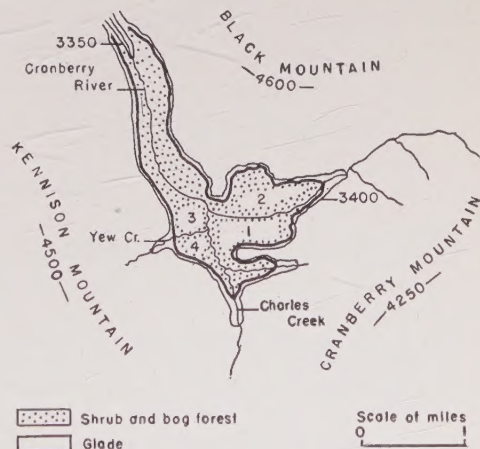


FIG. 2.—Level bog area. Dotted area shows location of shrub and bog forest of about 480 acres; white area represents open glade. Nos. 1, 2, 3, and 4 show, respectively, location of Big Glade (60 acres), Long Glade (20 acres), Flag Glade (28 acres), and Round Glade (8 acres).

at the lower end (fig. 2). It is apparently level but has a drop of 45 feet in 3 miles.

age flow from the hillsides. Black and Kennison mountains are capped by 500 feet of New River sandstone and massive shales of the Pottsville series, which in

base level, but streams $1\frac{1}{2}$ miles from their spring source and 3400 feet above sea level usually cut V-shaped valleys, as Cranberry River is doing below the bogs.

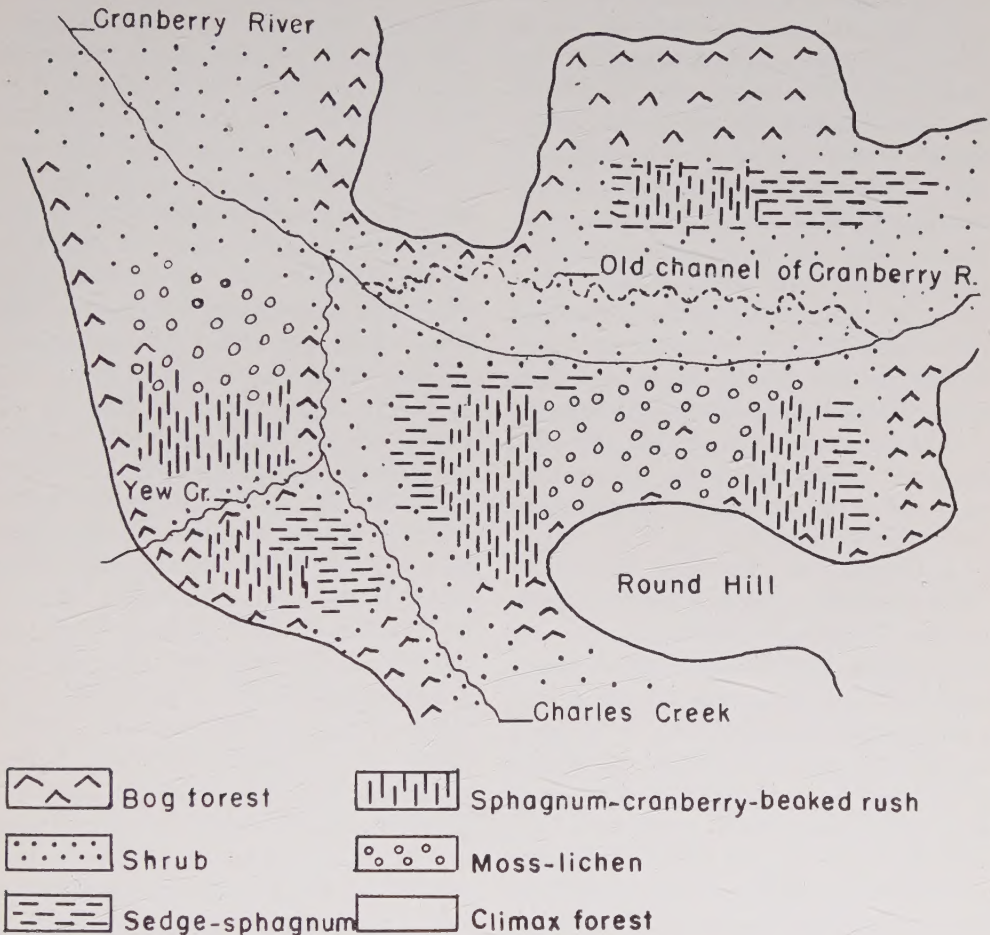


FIG. 4.—Community distribution over the area

erosion form sharp ridges not receptive to rainfall and melting snow.

ORIGIN OF LEVEL AREA

The writer early was confronted with the puzzling question of the origin of a wide valley so near the source of a stream. This is no ordinary occurrence. Mature rivers may develop wide valleys by lateral cutting when approaching

So far as can be learned, no explanation of this unusual situation has been attempted other than a suggestion that a mountain lake has been filled with sediments and plant remains, thus producing the level area. Yet before a lake could have existed, the widened valley had to be formed. Two possible methods of widening were given consideration.

I. ORIGIN BY SINKING.—Solution of

limestone below shales and sandstones may cause a collapse of strata, thus forming depressions and often lakes. The fact that the bottom of the peat at the center of Big Glade (figs. 8, 9) is 8 feet lower than the bank of Charles Creek at the lower end of this glade is suggestive of a sink here. Furthermore, the Greenbrier limestone lies beneath this area at an elevation sufficiently above the valley of Hill's Creek to the south to permit underground drainage of the Cranberry Glades area to the Greenbrier River through Hill's and Locust creeks. However, the strata beneath the bog consist of at least 800 feet of shales and sandstones, which should stand up—even with solution of the limestones beneath. It is therefore improbable that there has been any collapse of strata here to form or to aid in the formation of the widened valley by erosion.

2. ORIGIN BY SURFACE EROSION.—

With the uplift of the Schooley peneplain at the close of the Cretaceous, the streams began anew their work of erosion and dissection. Greenbrier River took its course southwestward with the outcrop of the less-resistant strata of the Mauch Chunk and Greenbrier series. Cranberry River and others to the north took their courses to the northwestward with the slope of the peneplain, due to warping in the uplift. The location of the head of Cranberry River is in a critical position in two respects: (a) it is near the beginning of the slope of the peneplain westward; (b) it is in a location of increased dip of strata. Measurements show that from the top of Cranberry Mountain to the center of the bog area, a distance of 3 miles, the dip is 275 feet to the mile, while for the next 5 miles downstream the dip is 125 feet to the mile. This condition caused the upper few miles of the stream to cut in mostly softer rocks,

while the remainder was cutting in hard sandstones and conglomerates.

During Tertiary time Greenbrier River cut down much faster than Cranberry River because it was cutting in soft rock while the latter was cutting in very resistant sandstones and conglomerates. By the close of the Tertiary, Greenbrier River had cut down to near the bottom of the Greenbrier limestone, 2100 feet below the Schooley level, and had formed a partial peneplain (Harrisburg) in the less resistant area—as evidenced by the Hillsbora plain, Jerico Flats, Key Flats, and other points. During the same time, Cranberry River and its branch, Charles Creek, had cut down about 1200 feet. The upper parts, cutting in soft strata, reached temporary base level in the Mauch Chunk shales, the level being controlled by the hard layers downstream. Sideward cutting in soft rock then allowed the streams to widen their valley to these unusual widths. It is to be noted, however, that they were considerably longer then than now and were gradually shortened by the rapid downward cutting of Greenbrier River and the piracy of its branch, Stamping Creek, westward into the drainage basin of Cranberry River and its branch, Charles Creek, thus moving the divide farther westward. The widened valley is thus a part of the Harrisburg peneplain, the writer believes, although it is 1000 feet above the Hillsbora level.

Another uplift at the close of the Tertiary caused the Greenbrier to entrench 400 feet into the Harrisburg peneplain to the present level. No such entrenching occurred in the Cranberry Glades area, owing to the slow cutting of the river in the very resistant conglomerate below the level area. Widening probably continued, but more slowly, as the rejuvenation of the branches of Greenbrier River

led to further piracy and shortening of Cranberry River and Charles Creek.

Soils

SOIL OF SURROUNDING HILLS

The profiles of the bog were examined carefully, and some attention also was given to the soil of the surrounding area to the top of Kennison Mountain, 1100 feet above the bog. The soils of Cranberry Mountain and the lower parts of Kennison and Black mountains are derived from mixtures of the many-colored shales and sandstones of the Mauch Chunk series with more or less humus. On Cranberry Mountain the soil is deeper and contains more humus than on Black Mountain, because of less exposure to the sun, more spring and seepage flow, and fewer fires. Kennison Mountain is intermediate in these respects. Soil tests for acidity in the surrounding area show a range from pH 4 in spruce forest on top of Kennison Mountain to pH 6.2 on Cranberry Mountain in maple-birch forest. No neutral or alkaline soil was found.

SOIL OF BOG

Figure 3 shows the location of many profile samples along various transects in the area. All parts of the bog have been sampled in order to obtain a clear picture of the accumulated sediments and peat. More than 150 borings were made, with a Hillier peat-borer.

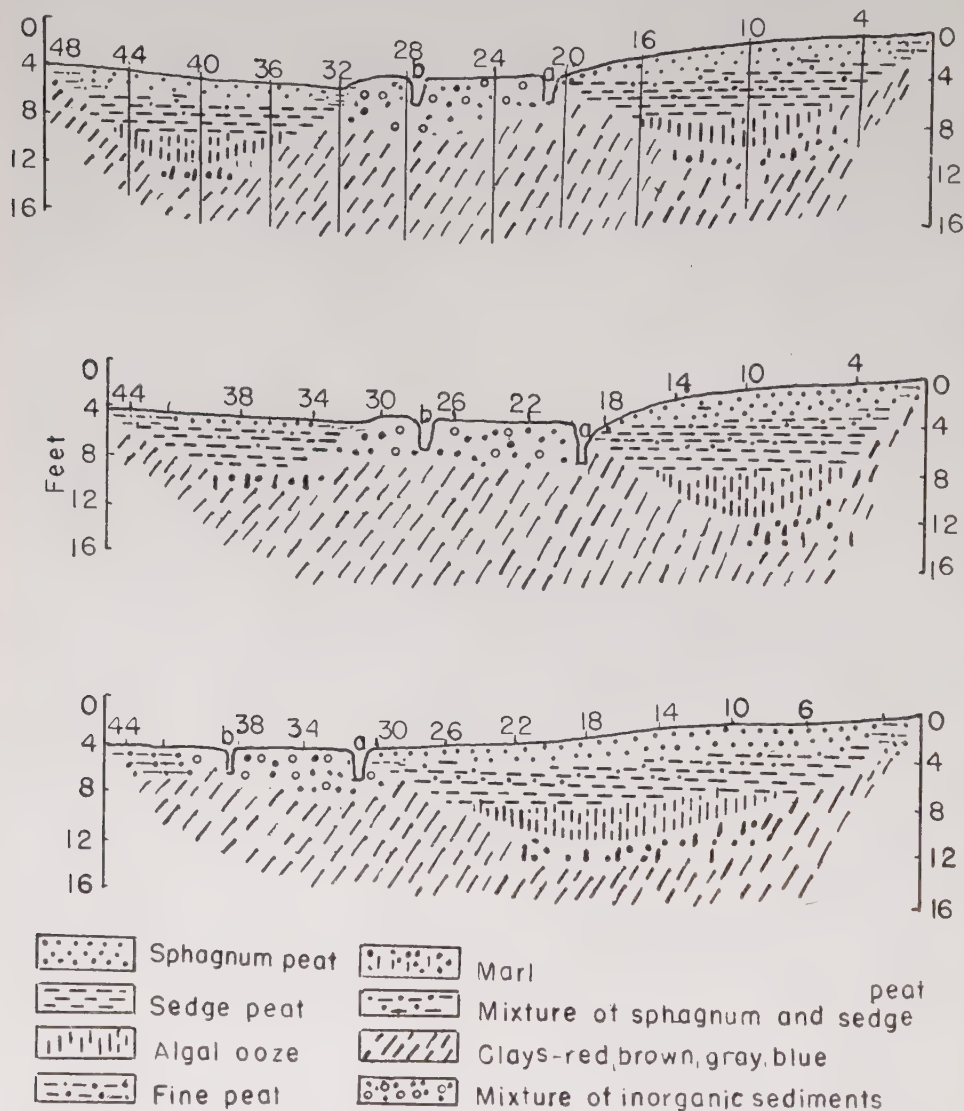
TRANSECT A.—This transect passes from Round Hill on the south directly north across the middle of the upper half of Big Glade, across a belt of alders along Cranberry River, and across Long Glade into spruce forest north of Long Glade, a distance of 2400 feet (fig. 3). Borings were made at intervals of 50 feet to varying depths. Generally samples were taken as deeply as the borer could be

pushed into the very stiff compact clay. Fifteen feet was the maximum depth from which it could be recovered by two men.

The profile revealed by this transect is shown in figure 5. Stations 1–20 show the profile of Big Glade, beginning at its southern margin at Round Hill. Station 1 is 50 feet inside the margin of the bog and shows 4 feet of fine peat with many logs. Below this are 2 feet of clay and sand underlain by rock. Between this station and the base of the hill several other borings showed that the peat thinned to 1 foot at a distance of 3 feet from the base of the hill and was only 1 foot above rocky material. Station 2, 100 feet from the base of the hill, shows 5 feet of fine peat overlying 3 feet of a mixture of clay and organic material underlain by very compact clay. Stations 1 and 2 are within a belt of shrubs, about 125 feet wide. Station 3 is 25 feet from the border of the shrub belt, in the glade. Samples taken here show $6\frac{1}{2}$ feet of peat, including $1\frac{1}{2}$ feet of sphagnum peat at the top, 3 feet of sedge peat mixed with sphagnum peat, 1 foot of sedge peat, and 1 foot of algal ooze. Below the peat are 2 feet of compact sticky clay. The next eight borings show similar profiles, with a gradual thickening of the peat to $8\frac{1}{2}$ feet at the midway point across Big Glade. Station 11, 15 feet in depth, shows respectively from top downward 2 feet of sphagnum peat, $2\frac{1}{2}$ feet of sphagnum and sedge peat mixed, 2 feet of sedge peat, 2 feet of algal ooze, 3 feet of marl, and $3\frac{1}{2}$ feet of clay. The next nine stations show a similar profile, with gradual thinning of the peat to 2 feet at station 20 at the border of the shrub belt on Cranberry River. Underneath the peat is clay as far as samples could be taken. Station 21 is on the north side of Cranberry River,

and a boring made with a 2-inch pipe to a depth of 11 feet shows only fine sediments of clay and sand.

5 feet deep. It may overflow its banks during floods and deposit inorganic sediments. As a result, stations 21-27 show



FIGS. 5-7.—Fig. 5 (above), transect profile A. Fig. 6 (center), transect profile B. Fig. 7 (below), transect profile C. Horizontally, 1 inch equals 530 feet; vertically, 1 inch equals 16 feet. Vertical exaggeration is approximately 33. *a*, present location of Cranberry River; *b*, old channel.

From Big Glade, transect A crosses Cranberry River and a belt of shrubs, mostly alders, 660 feet wide between Big Glade and Long Glade. Cranberry River is about 12 feet wide here and in flood is

a profile of fine sediments, mixed with organic materials in some places. They were very difficult to bore. Stations 29-34 show peat 2-5½ feet in thickness, with clay beneath, as in stations 1 and 2.

Stations 35-44 are in Long Glade, with a profile similar to those in Big Glade, although the peat is only 7 feet thick at the deepest part. Stations 45-48 extend through a belt of alders on the north side of Long Glade and into spruce forest. Here the peat is 4 feet thick at station 44 and thins to 1 foot at station 48. Underneath the peat are 3-4 feet of red clay from the red Mauch Chunk shales on the hills to the north.

TRANSECT B.—This transect, beginning at Round Hill on the south side of Big Glade (figs. 3, 6), crosses an alder belt 120 feet in width, passes through the center of Big Glade, and then crosses a shrub belt to slightly north of the western end of Long Glade. The total length is 2200 feet. Stations 1-3 are similar to 1-3 in transect A. Stations 4-18 are similar to 4-20 in transect A, except that the peat is 2 feet thicker on the average and the thickness of the algal ooze is greater. Stations 10 and 11, near the center of Big Glade, show the deepest peat in any part of the entire area, 11 feet in thickness. Clay and sand extend below the peat 5 feet or more. At station 10 samples were taken for pollen analysis (figs. 3, 6, 13). Temperature readings (fig. 12) were taken here also. The different layers represented are: 2 feet of sphagnum peat, 3 feet of sedge and sphagnum peat mixed, 2 feet of sedge peat, 4 feet of algal ooze, 3 feet of marl, and 1 foot or more of clay.

This area, showing the greatest depth of sediments, appears to be a sink in the general surface underlying the peat and supports the theory of formation of the level area by solution of limestone beneath shales and sandstones. Since it is unlikely that there has been any sinking, however, the depression will be explained by another process in a later section.

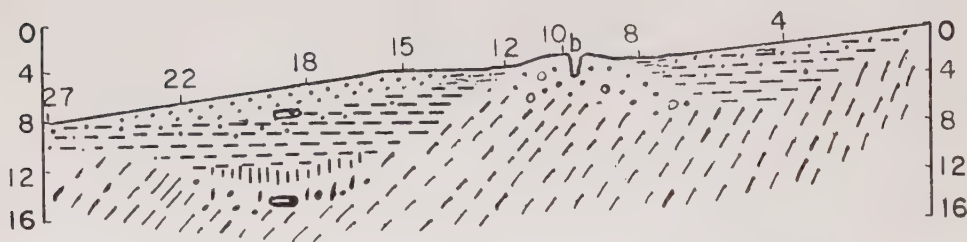
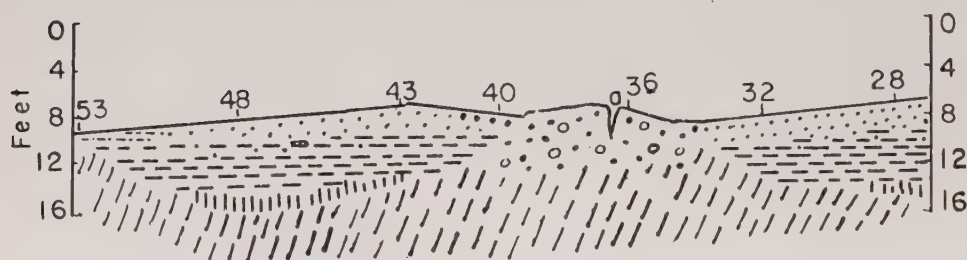
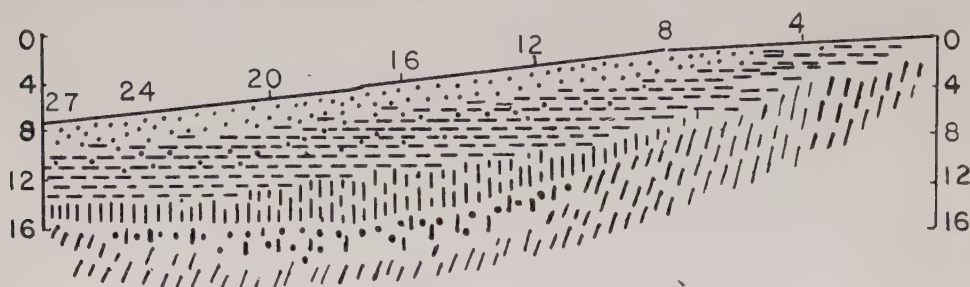
TRANSECT C.—This cuts across Big

Glade in its lower part (figs. 3, 7). There are forty-four stations 50 feet apart, a total length of 2150 feet. It extends from the alder belt on the south side of Big Glade to the foot of Black Mountain. The section across Big Glade is similar to the corresponding section of transect A, with the exception of a 6-inch greater average thickness of peat. Stations 31-38 extend across the floodplain between Cranberry River and its old channel and reveal a profile of inorganic sediments similar to stations 21-28 of transect A. This area is practically level. Stations 39-44, which are north of the old channel, exhibit 1-1½ feet of fine peat accumulation. Station 30 of this transect, as well as 18 and 20 of transects B and A, respectively, shows that Cranberry River is now eroding into the peat of Big Glade.

TRANSECT D.—This is the longest transect, extending from the upper end of Big Glade in almost an east-west direction the full length of Big Glade, the belt of alders on Charles Creek, the width of Flag Glade, and the belt of alders and spruce west of Flag Glade to the foot of Kennison Mountain, a total length of 5200 feet (figs. 3, 8, 9). There are fifty-three stations at 100-foot intervals. It crosses transects A, B, and C at their deepest parts, and its profile is similar to theirs, with a gradual thinning of the peat toward either end of Big Glade but with almost a uniform thickness from transects A to C. The profile of the shrub belt on Charles Creek is similar to that of the other alder zones. In Flag Glade the peat is thinner than in Big Glade, not more than 8 feet thick at any point. The top surface of this profile shows a drop in elevation of 8 feet in the length of Big Glade, about equal to the drop in Cranberry River, which parallels it. There is a rise in elevation of 1 foot from the lower end of Big Glade to the bank of

Charles Creek. The lowest depth of peat in station 20 of this transect is 8 feet lower than the banks of Charles Creek at

TRANSECT E.—This transect (figs. 3, 10) extends from the south side of Round Glade in a slightly northwest direction



FIGS. 8–10. —Fig. 8 (above) and fig. 9 (center), transect profile D. Fig. 10 (below), transect profile E. Horizontally, 1 inch equals 584 feet; vertically, 1 inch equals 16 feet. Vertical exaggeration is approximately 36.5. *a*, location of Charles Creek; *b*, of Yew Creek.

the lower or west end of Big Glade and 4 feet lower than the south bank of Cranberry River on the north side of Big Glade.

across Round Glade, the shrub belt on Yew Creek, Flag Glade, and into the alder zone north of Flag Glade. It includes twenty-seven stations at 100-foot inter-

vals, totaling 2600 feet. Stations 2-7 show the profile of Round Glade, with the thinnest accumulation of peat of any of the glades, not exceeding $4\frac{1}{2}$ feet. The peat is mostly sedge peat. Near the banks of Yew Creek the profile is similar to those cutting through the other streams, chiefly of inorganic sediments. The profile in Flag Glade is similar to that of Big Glade, but the peat does not exceed 8 feet at any point. The surface of the peat in Flag Glade shows a drop of 5 feet in elevation from the upper end at station 11 near Yew Creek to station 27 at the lower end.

WATER TABLE.—At the intersection of transects B and D in the center of Big Glade (fig. 3), a pit 5 feet deep was dug in 1934. The water level was read on a stake with an inch scale, driven into the pit, from April 12 to November 11, 1941 (fig. 11). On April 12 the water stood 1 inch below the peat surface, the highest recording at this station. On October 25 it was 12 inches below the surface, the lowest level recorded. This pit (designated as A) was in a *Polytrichum-Cladonia* community. A similar pit (B) was dug in Long Glade at station 38, transect A, in a *Sphagnum-Vaccinium-Rhynchospora* community, and readings were made during the same period. Here the water level was 2 inches above the peat surface on April 12, and $7\frac{1}{2}$ inches below on October 25. The water table was 2-5 inches higher continually than in pit A. Observations were made on the water table in the shrub belts along Cranberry River and Charles Creek. Pit C was located at station 31 of transect A in an *Alnus-Viburnum* community, and the shifting level was very similar to that of pit B. The lowest water table is between Cranberry River and its old channel on transect A, with a fluctuation of from 8 to 30 inches below the surface.

During 1935, 1937, and 1938, observations were made on the water table at irregular intervals. It is generally lowest in September and October.

SOIL TEMPERATURE.—At station 10, transect B, temperatures of the bog were taken from April 12 to November 11: at the surface of the peat beneath the moss, at the 6-inch depth, at the 1-foot depth, and at intervals of 1 foot down to a depth of 10 feet (1 foot above the bottom of the peat). A soil thermometer was used which was fastened to a pole for the

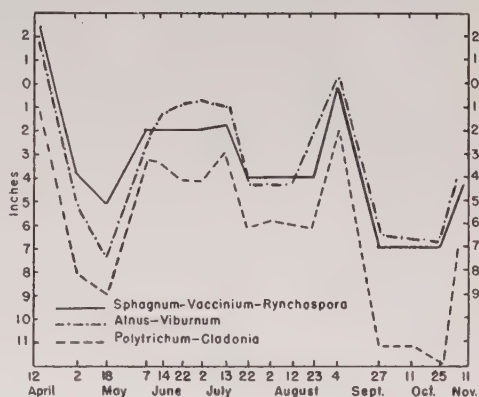


FIG. 11.—Fluctuations of water table in three communities; zero mark represents surface of peat underneath growing moss.

lower levels. It was pushed into the peat to the required depth and left for 12-15 minutes, then pulled up quickly and the temperature recorded. Readings were taken between 2:00 P.M. and 4:30 P.M.

The surface temperature varied from 32° in April to 68° in August, while in the lowest level it rose gradually from 46° in April to $49\frac{1}{2}^{\circ}$ in October (fig. 12). The low levels are little affected by the increase of heat on the surface through the summer. They reach their maximum temperature more than a month after the surface has reached its maximum and has begun to decline rapidly. Early in October these lower layers are still gaining in

heat and do not begin to show a net loss until the middle of October. Values for

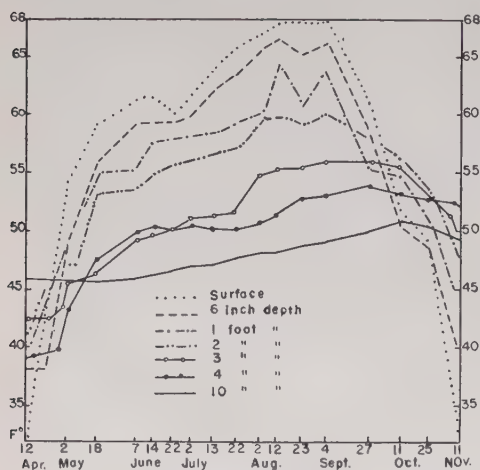


FIG. 12.—Temperature of bog profile at station 10 of transect B.

any time. The 5-, 6-, and 7-foot levels were 3° – 6° colder in winter and 2° – 5° warmer in summer than the 10-foot level.

The temperature of the bog soil is no doubt influenced by the water from hundreds of cold springs which flows into it, especially from Cranberry Mountain (fig. 2). The temperature of the spring water changes little during the 12 months (44° to 54°). This water tends to maintain uniform temperature in the bog throughout the year, especially in the lower levels.

Temperatures of the profile were checked in other communities. Only the surface temperatures were found to vary from those of the above profile. The surface of a profile with a higher water table

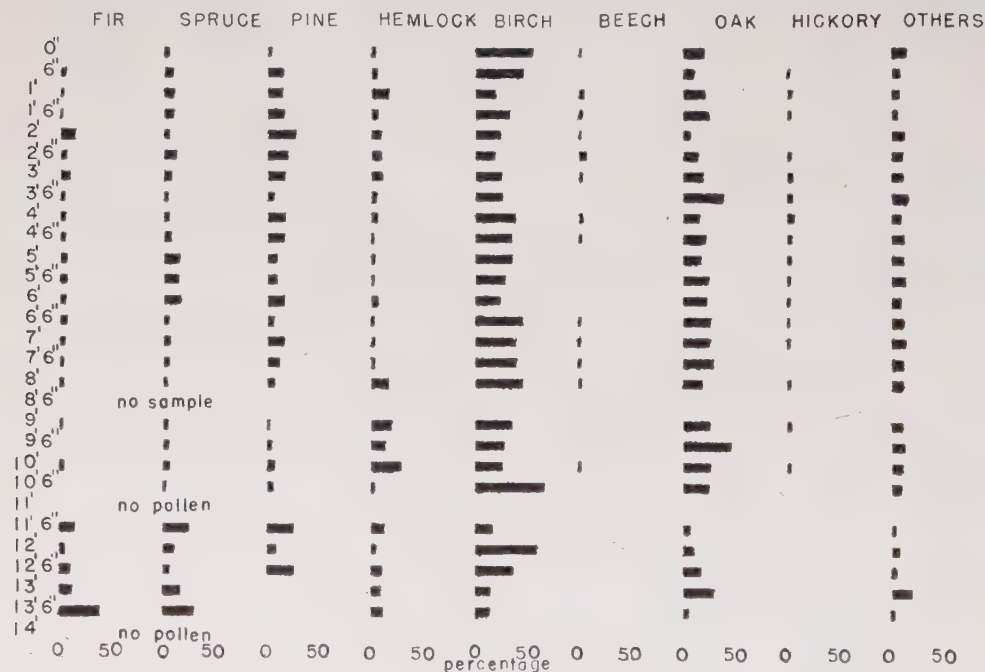


FIG. 13.—Pollen diagram at station 10, transect B. (Pollen analysis of samples by PAUL B. SEARS)

the 5–9 foot levels are omitted in figure 12. The 8- and 9-foot levels did not vary from the 10-foot level more than 1° at

will show 1° – 2° lower temperature than one with a lower table after both are exposed to the sun for several hours.

SOIL pH.—At station 10, transect B, the pH profile was also determined colorimetrically to a depth of 10 feet. The values, beginning at the surface, are: surface and 6-inch levels, pH 3.8; 1- and 2-feet, pH 4; 3-, 4-, and 5-feet, pH 4.4; 6-, 7-, and 8-feet, pH 4.6; 9- and 10-feet, pH 4.8. The peat, although slightly less acid at the lower levels, is still very acid at 10 feet. KURZ (5) found in Illinois bogs a decrease in acidity with increase in depth. This high acidity in the lower levels may be caused, as KURZ suggested, by sphagnum remains in the peat or by the downward movements of water. The pH of the surface layers was also determined in the various plant communities, and the results are given in the community descriptions.

POLLEN PROFILE.—At station 10, transect B (which is also station 16, transect D, at the center of Big Glade), samples of the sediments were taken at 6-inch intervals from the surface to the 14-foot level. The pollen diagram (fig. 13) shows the results. The 13½-foot level shows a spruce-fir dominance. From that level to the surface the spectra are similar to the surface or present level, with the exception of the absence of fir at the surface level. The 12-foot level in marl and the 8-foot in algal ooze show little difference from the present level, indicating that all the sediments from the 13-foot level to the surface were deposited while the surrounding vegetation was similar to the present.

Vegetation

REGIONAL CLIMAX

The variation in altitude (3400–4600 feet) allows the persistence of three climaxes: northeastern coniferous or boreal forest, transition forest, and eastern deciduous forest. On Round Hill at 3550 feet a quadrat study shows the following,

based on stem count: 70 per cent *Acer saccharum*, 4 per cent *Fagus grandifolia*, 10 per cent *Betula lutea*, 6 per cent *Prunus serotina*, 5 per cent *Tilia americana*, and 5 per cent *Prunus pennsylvanica*.

At 4100 feet on Cranberry Mountain the climax is a transition forest of yellow birch, sugar maple, beech, spruce (*Picea rubra*), and hemlock (*Tsuga canadensis*), with *Ostrya virginiana* as a smaller tree and *Corylus rostrata* as the most common shrub. A quadrat study shows 30 per cent *Betula lutea*, 33 per cent *Acer saccharum*, 20 per cent *Picea rubra*, 6 per cent *Fagus grandifolia*, 5 per cent *Tsuga canadensis*, and 6 per cent *Ostrya virginiana*.

Above 4200 feet the maple loses its dominance to spruce. On Kennison Mountain at 4500 feet a quadrat study shows 65 per cent *Picea rubra* and 30 per cent *Betula lutea*. *Abies fraseri* has not been found in this area with the spruce and birch, although in other parts of the state it does occur with these two species (3). *Taxus canadensis* is often found in this area as a low shrub. The range of mountains, including Black and Kennison, is known as "Yew Mountains" because of its abundance. The elevations where spruce dominates are somewhat lower than the 5000-foot lower limit in Tennessee and North Carolina, 400–500 miles farther south. Soil factors as well as climatic ones may have some influence on the zonal limits. *Populus tremuloides* and *Prunus pennsylvanica* have been observed as chiefly occupying a burned-over area.

VEGETATION OF BOG

The entire level area of 600 acres popularly called Cranberry Glades may properly be classified as bog. Peat covers most of the area, varying in thickness from a few inches to 11 feet. The entire

area is acid, ranging pH 3.8-6.2. The soil of all communities where sphagnum or other moss grows is near pH 4 and about pH 6.2 where no moss grows. All the area except a part of the shrub communities is partially covered with sphagnum, and there are a number of genera of the heath family, such as *Andromeda*, *Menziesia*, *Vaccinium*, and *Gaultheria*. The water table is within an inch of the surface most of the year and sinks to 12 inches below only during dry periods. This water in the partially decayed vegetable matter gives a quaking effect to the area wherever the peat is 5 feet or more in thickness. Carnivorous plants are represented by *Utricularia cornuta* and *Drosera rotundifolia*.

ORIGIN OF BOG CONDITIONS.—RIGG (7) mentioned two ways that bogs may develop: (a) in lakes and (b) in swamps. The popular belief is that this area was once a large mountain lake. Suggestions of dam formation by beavers or by landslide have been offered as possible causes of the lake. As the work progressed, this theory appeared inadequate for explanation of the existing conditions. During the last year of study, after checking the levels of the area, the lake theory of origin was abandoned as improbable if not impossible for three reasons: (1) The elevation of the lower end of the bog area is 45 feet lower than the upper end, at both the surface and the bottom of the peat, and the width of the area at the lower end is 400-500 feet. A dam 45 feet in height and 500 feet in length would have been required to flood the entire area, the construction of which would have been beyond the power of beavers or such landslides as could have occurred here. (2) If the whole area had been flooded, the deepest peat and certainly the deepest algal ooze and sedimentary peat should be found toward the lower

end of the area; this is not the case, for the deepest peat and algal ooze is toward the upper end (figs. 6, 8). (3) If the origin had been in a lake, the peat deposits should cover the whole area, even under the streams. The profiles show chiefly inorganic sediments under all the streams. The peat accumulations thin out toward the streams and do not extend under them.

Another theory, which will better explain the existing conditions, attributes the damming to stream action. The maps and profiles (figs. 2, 3, 5-10) show that the main peat accumulations are located in the angles of the junctions of the streams. This led the writer to the theory that the conditions giving rise to peat accumulation owed their origin to the streams. Apparently the whole area, described previously as a part of the Harrisburg peneplain at the close of Tertiary time, was 10-15 feet lower than at present. It had been widened and base-leveled by the then longer streams while the river farther down was cutting in much harder rocks. The slope of the area may at that time have been less than the 45 feet in 3 miles shown at present. Following this period there came a change from degrading to aggrading action, and inorganic sediments were deposited as levees along the stream courses, thus damming areas away from the streams in which water could accumulate. Some explanation must be found for the change from degrading to aggrading action. This could have happened possibly during the later part of the glacial period, when increased precipitation, decreased evaporation, and lesser vegetation cover on the slopes caused the swollen streams to be overloaded with sediments, which were deposited over the level area. The coarser sediments would be deposited nearer the stream courses as levees, and the finer

clays would settle out later in the ponded water in the depressions away from the streams. The marl and algal ooze may have been deposited during this period while the climate was too cool for many aquatic seed plants. During the post-glacial period the levee building continued, but more slowly because of less precipitation, more evaporation, better vegetation cover, and a shortening of the streams through further piracy by Stamping Creek. The coming of a warmer climate speeded up plant growth in the ponded water, filling it with peat and initiating the sedge swamp.

Figure 3 and the transect profile A (fig. 5) show that the old channel of Cranberry River was building a much wider levee on its left bank. This was due to a bend in the stream to the right, so that most of the overflow was on the left. This bend also was one probable cause of the change of course later to the south side of the levee and along the margin of the peat accumulation in Big Glade, explaining the wide extent of inorganic sediments now on the right bank of Cranberry River and its erosion into peat on its left bank, both of which had puzzled the writer for several years.

Levee building, which thus probably occurred through part of the glacial and post-glacial periods, has now probably ceased in most parts of the bog. Cranberry River has recently cut through the very resistant Princeton conglomerate and is now cutting in the soft Hinton strata for several miles below the glades. Since the stream there has a drop of almost 100 feet to the mile, it should cut down rapidly, thus rejuvenating the streams of the glades. There is evidence that this is occurring in the recent shifting of Cranberry River from its old meandering channel to a nearly straight course along the side of Big Glade (fig. 3).

This theory explains all the conditions existing at present, including the sink in Big Glade referred to earlier. The bottom of peat here is 8 feet lower than the bank of Charles Creek. This could have been a former stream bed, 3-4 feet lower than the surrounding area, permitting a deeper ponding of water. The profiles show that the present surface of peat in some of the glades is higher than the levees which assisted in its origin. This is the condition of the "raised" bog (7). Once peat accumulation is started, it may form its own dam owing to slow movement of water through it and can develop on a slope, especially in cool climates (4). Parts of Flag Glade on transect D show this condition, as do also parts of Big Glade. The levees produced the undrained condition which was necessary to start bog development.

SHRUB COMMUNITIES.—These communities cover approximately 400 acres and extend as a wide belt along the streams and around the margin of the glades (figs. 4, 14). On the basis of soil, moisture, and floristic composition two units may be recognized, designated the *Alnus-Sambucus* and *Alnus-Viburnum* communities.

The *Alnus-Sambucus* community occurs on the levees or floodplains near the streams, where the water table varies from 1 to 30 inches below the surface. The soil is alluvium with some humus. The soil reaction is pH 6-6.2. The chief shrubs are the alder and elder, although some others are found. A quadrat study shows 70 per cent *Alnus incana*, 20 per cent *Sambucus canadensis*, 2 per cent *Ilex monticola*, 2 per cent *Viburnum dentatum*, 3 per cent *Taxus canadensis*, and 3 per cent *Crataegus* sp. In some parts of the community scattered trees occur, including *Fraxinus nigra*, *Prunus sero-*

tina, *P. pennsylvanica*, *Betula lutea*, *Tsuga canadensis*, and *Picea rubra*.

Many herbaceous plants occupy the ground stratum of this community, their societies giving seasonal aspects to it.

tus, *A. prenanthoides*, *Trautvetteria carolinensis*, *Aconitum uncinatum*, and *Chelone glabra*. As a part of the aspection should be included woolly aphids on *Alnus incana*, forming great white masses



FIGS. 14-17. Fig. 14, *Sphagnum-Vaccinium-Rhynchospora* community with sedge, shrub, bog forest, and climax forest of Kennison Mountain in distance. Fig. 15, *Polytrichum-Cladonia* community in Big Glade with patch of *Andromeda glaucophylla* and shrub belt along Charles Creek. Round Hill is on left and Kennison Mountain on right. Fig. 16, shrub and bog forest invading *Polytrichum-Cladonia* community in Flag Glade. Shrub is chiefly *Viburnum cassinoides*, which aids in hummock formation. Kennison Mountain at back. Fig. 17, young *Picea rubra* in *Polytrichum-Cladonia* community. This spruce, 5 feet in height, had horizontal roots 9 feet long between moss mat and peat surface.

The vernal societies include *Claytonia caroliniana*, *Viola cucullata*, and *Ranunculus septentrionalis*. The estival societies include *Phlox maculata*, *Thalictrum* sp., *Veratrum viride*, *Ribes prostratum*, *Senecio aureus*, and *Carex scoparia*. The autumnal aspect is given by *Aster panicula-*

2 feet in length on the branches and visible at half a mile. These occur through June, July, and August.

The *Alnus-Viburnum* community is found around the margins of all the glades. The elevation is about 12-18 inches lower than the *Alnus-Sambucus*

community, and the water table varies from 2 inches above the surface to 7 inches below. Surface soil reaction is pH 4.4. *Sphagnum palustre* grows over much of it, and there is an accumulation of peat or organic material to a depth of from a few inches to 5 feet. The total area is greater than that of the *Alnus-Sambucus* community. A quadrat study shows 40 per cent *Alnus incana*, 25 per cent *Viburnum cassinoides*, 7 per cent *Ilex verticillata*, 8 per cent *Amelanchier oligocarpa*, 8 per cent *Pyrus melanocarpa*, 4 per cent *Pyrus americana*, 5 per cent *Menziesia pilosa*, and 3 per cent *Hypericum densiflorum*. Seasonal aspects also occur under the shrubs in the vernal societies of *Caltha palustris*, *Symplocarpus foetidus*, *Ranunculus septentrionalis*, and in the estival societies of *Polemonium vanbruntiae*, *Arisaema triphyllum*, *Thalictrum* sp., *Oxalis acetosella*, *Osmunda cinnamomea*, *O. regalis*, *Rosa carolina*, and *Sium cicutaefolium*. The main factor differentiating these two communities is the difference in the depth of water table and possibly the amount of organic material of the soil. The difference in acidity is due chiefly to sphagnum, which is absent from one community.

CAREX-SPHAGNUM COMMUNITY.—This community extends around the eastern and western margin of Big Glade and the eastern margin of Flag Glade. It also occupies most of Round Glade, the upper half of Long Glade, and the margins of the remainder of Long Glade (figs. 4, 14). The main species of sedge is *Carex rostrata*, which extends throughout the community and makes up at least 90 per cent of the total sedge population. In some parts of the community rather extensive stands of *Carex trisperma*, *C. scirpoides*, and *C. lurida* occur. The sphagnum here is mostly *S. capillaceum*, with some *S. palustre*. This community includes also more or less of *Rubus hispi-*

dus, *Vaccinium macrocarpon*, and *V. oxycoccus*. Little aspection is obvious after growth of sedge begins in the spring.

From 1 to 6 feet of peat underlie this community. The water-table level and pH value, 4.4, are close to those of the *Alnus-Viburnum* community, which borders it and is invading it, and to those of a *Sphagnum-Vaccinium-Rhynchospora* community, which also borders it. In some places *Carex rostrata* has encroached upon the latter community as much as 15 feet in 8 years through growth of its underground rootstocks. In other places the ecotone of the two communities has not changed in 8 years; in others sphagnum has spread into pure sedge areas. Since 1–2 feet of sphagnum peat overlies 4–5 feet of sedge peat in much of the glades, sphagnum must have grown upon and killed out the sedges which first formed the peat. It is difficult to understand how sphagnum could kill out *Carex rostrata*, since the latter can invade sphagnum areas and by means of its rootstocks adjust itself to any building up of peat by sphagnum. The sedge or sedges which first formed the peat may have been acid-intolerant, existing for a long period in the absence of sphagnum and acid. With the invasion of sphagnum and the induced change in environment, they succumbed.

SPHAGNUM-VACCINIUM-RYNCHOSPORA ASSOCIATION.—This community includes a total of 50 acres in the upper and lower ends of Big Glade, the lower half of Long Glade, the upper one-third of Flag Glade, and a part of central and western Round Glade (figs. 4, 16). The percentages of each of the components of this association would be difficult to determine. *Sphagnum capillaceum*, *S. palustre*, *Vaccinium oxycoccus* (small cranberry), and *Rhynchospora alba* (beaked rush) are present throughout the area. *Rubus hispidus* and *Vaccinium ma-*

crocarpon may or may not be present and in varying abundance. Through the summer the beaked rush gives the meadow aspect, which is modified in some parts by an abundance of two species of orchids (*Pogonia ophioglossoides* and *Calopogon pulchellus*); the autumnal aspect is given by *Eriophorum virginicum* (cotton grass), with large cotton-like masses of fruit. Cotton grass extends more or less through all the communities, giving the autumnal aspect to the whole area except the shrub and bog forest communities. *Aster umbellatus*, *Dulichium arundinaceum*, and *Epilobium densum* also add to the autumnal aspect of this association in Long Glade and in some other parts.

The reaction of the soil is pH 4. The water table varies from 2 inches above the soil surface to 7 inches below during droughts. Much of the time the water table is at the surface of the partially decayed sphagnum material, permitting the live sphagnum to be filled with water continually. The water-table level is one of the main factors determining this community, which is always located in the poorly drained areas. The upper end of Big Glade is nearly level and receives water from seepage, springs, and small streams from Cranberry Mountain; the lower end is nearly level and has its water table raised somewhat by overflow from Charles Creek, which is more than 1 foot higher. The upper end of Flag Glade is almost level and receives water from overflow and seepage from Yew Creek and springs from the hills. The lower half of Long Glade is lower than the levee or floodplain of the old channel of Cranberry River, which extends close to the protruding hill on the west and cuts off drainage by its levee at that point (fig. 3). Soil temperature is possibly another factor in determining this community. Temperature at the surface is always 1°–

3° lower than in the *Cladonia-Polytrichum* community. This difference in temperature is partly due to the higher water table and partly to the influence of cold springs. This association is being encroached upon by *Carex rostrata* in some places and by *Polytrichum strictum*, *P. ohioense*, and *P. commune* in others—where the water table is being lowered.

POLYTRICHUM-CLADONIA ASSOCIATION.—This community is limited chiefly to Big Glade and Flag Glade and occupies about two-thirds of each. It occurs in the part of Big Glade between the *Sphagnum-Vaccinium-Rhynchospora* association on the east and west sides of this glade and also in the northwestern part of Flag Glade (figs. 4, 15). The total area is 50–60 acres. This association includes *Polytrichum strictum*, *P. ohioense*, *P. commune*, *Cladonia rangiferina*, and *C. tenuis*. There may be more or less of *Rubus hispidus* and *Eriophorum virginicum*, the latter giving the autumnal aspect to the association. The aspect changes with the development of lichens. During periods of rainy weather and high water table, *Cladonia* grows very rapidly, spreading over whole clumps of *Polytrichum*, so that much light gray color is mixed with the green. During long periods of drought the lichen is deprived of water and dries so that it can be crumbled to powder, while the moss with long stems extending to the moist peat or organic soil then will grow around and over it.

The reaction of the soil surface in this community is pH 3.8, increasing somewhat at lower levels. The water table is 3–6 inches lower than in the communities surrounding it. The lower water table and the lower pH have the same cause. The association in Big Glade is higher than Cranberry River on its north, and it lies along the north side of Round Hill. This deprives it of any water from seep-

age, springs, or streams, leaving rainfall its only source—which is void of mineral bases capable of neutralizing the acidity. The *Sphagnum-Vaccinium-Rhynchospora* association at the upper end of this glade receives the same amount of rainfall and in addition some water from the hills, thus producing a higher soil reaction and a higher water table. Similar conditions exist in the *Polytrichum-Cladonia* association in Flag Glade, also occurring on “raised” peat. It is higher than Charles Creek on its east and slopes toward the hill on the west and so is deprived of telluric water and bases, resulting in a low pH and a low water table. Wind sweep may also have some effect in determining this community. The central part of Big Glade and lower part of Flag Glade are most exposed to the winds moving through the valley. This would tend to lower the water table and increase transpiration, favoring *Polytrichum* rather than sphagnum.

The encroachment of sphagnum and *Polytrichum* upon each other is determined by the height of water table, by the amount and frequency of rainfall, and by the rate of evaporation. During periods of much rainfall and high relative humidity, sphagnum will grow over *Polytrichum*, cutting off its light and killing it. In many parts of the association this competition may be observed through the season. Where the water table is being lowered, as along Cranberry River on the north side of Big Glade, *Polytrichum ohioense* and *P. commune* are encroaching upon the *Sphagnum-Vaccinium-Rhynchospora* association.

Three colonies of *Andromeda glaucophylla* have become established in the *Polytrichum-Cladonia* association in Big Glade. One large and two small colonies cover nearly an acre (fig. 15). It has greatly increased its area in 10 years, sug-

gesting that it was introduced by bird dissemination of seeds from some other bog. A similar case is found in the *Sphagnum-Vaccinium-Rhynchospora* association, where two colonies of *Menyanthes trifoliata* have established themselves, one in Long Glade and one in Big Glade, and have spread greatly in 10 years. If they have been here for a long period, they should be more widely distributed over the area.

The *Polytrichum-Cladonia* community is being encroached on all sides by shrubs from the *Alnus-Viburnum* community. *Hypericum densiflorum* has driven a wedge into the association from Cranberry River on the north side of Big Glade. *Pyrus melanocarpa*, *Ilex verticillata*, and *Viburnum cassinoides* are scattered through much of the association.

Hummocks are found in many parts of this association, usually with the shrubs (fig. 16). As mentioned before, wind movement is strong, increasing evaporation, so that at times in the summer the water table descends to 12 inches below the surface of the soil. Growth of *Polytrichum* is thus slowed down many hours and days during the summer. Those moss plants growing under a small shrub with its protective canopy of leaves, such as *Viburnum cassinoides*, will remain more moist, with resultant longer growing periods, so that they elevate themselves above the surrounding moss. *V. cassinoides* can adjust itself to the upward growth of the moss by developing adventitious roots. One plant was observed with such roots 18 inches above the original ones. Other shrubs than *V. cassinoides* also assist in hummock formation. After a hummock is once started, the shrub may die and the hummock continue to grow, mostly on its leeward side.

A study was made of the roots of many of the bog plants. Most of them were in

the *Polytrichum-Cladonia* association. None of the shrubs scattered through this association are able to penetrate the acid peat but extend their roots horizontally on the surface or above it in the living moss mat. A specimen of *V. cassinoides* 3 feet in height had four horizontal roots 8-9 feet in length. *Hypericum densiflorum* 12 inches high had one horizontal root 6 feet long and two shorter ones. *Andromeda glaucophylla*, *Pyrus melanocarpa*, and *Gaultheria procumbens* of similar heights had roots of corresponding lengths. A red spruce 5 feet in height had twelve horizontal roots 6-9 feet in length (fig. 17). None of these roots had penetrated the peat vertically more than 1 inch. The plants are held up by the moss and could not exist without it. Only four of the species were able to penetrate the peat more than 1 inch. These were *Eriophorum virginicum*, *Rhynchospora alba*, *Menyanthes trifoliata*, and *Carax rostrata*. One plant of *E. virginicum* 2 feet high had roots extending vertically almost 2 feet. As previously mentioned, it is found over the whole area except in the shrub and bog forest communities and gives the autumnal aspection to the glades. Vertical roots of *C. rostrata* were found up to 18 inches long. *R. alba* penetrates the peat 6 inches with several vertical roots. *M. trifoliata* in the *Sphagnum-Vaccinium-Rhynchospora* association had roots 18 inches deep in the sphagnum material. It probably will extend its area in this association.

BOG FOREST ASSOCIATION.—This community, covering about 80 acres, is on the periphery of the entire bog area (figs. 14-16). Red spruce and hemlock are the most common species. A quadrat study shows 75 per cent *Picea rubra*, 12 per cent *Tsuga canadensis*, 8 per cent *Betula lutea*, 5 per cent *Fraxinus nigra*. The shrubs include *Ilex verticillata*, *Viburnum cassinoides*, *Rhododendron maximum*, and

Taxus canadensis. Sphagnum grows over much of the forest floor. The soil reaction is pH 4.5. The water table is high, only slightly lower than in the *Alnus-Viburnum* community, which forms an irregular ecotone with the bog forest and is being encroached upon by it. The soil is organic and varies in depth from 1 to 5 feet of peat.

In addition to invasion of the *Alnus-Viburnum* community, the bog forest is also invading the moss-lichen and sphagnum-cranberry-beaked rush communities, mostly in Flag Glade and Round Glade. Spruce is the only tree species invading the moss communities, except one specimen of *Pinus strobus* and three or four of *P. rigida* which have attained a diameter of 6-8 inches in Big Glade. It is very difficult for these trees to invade the moss communities, since their roots cannot penetrate the peaty soil and must run horizontally under the moss, so that they are soon casualties to the strong wind-sweep in the glades. If they can develop in a group of four to eight, they support one another. Many such groups occur in Big Glade and in Flag Glade, but show a slow rate of growth.

A study was made of the rate of growth of young spruce on Kennison Mountain, in the bog forest, and in the moss-lichen community of the open glade. Trees 2.5 inches in diameter were cut 1 foot from the soil, and annual rings were counted. The specimen from Kennison Mountain showed an age of 19 years; the one from bog forest, 49 years; and the one from the moss-lichen community, 31 years. The bark was equal in thickness on the mountain and bog forest specimens but was more than twice as thick on the glade specimen. The tree in the bog forest had two important limiting factors—difficulty of absorption and lack of sunlight. The one in the open glade was limited in absorption of water

and nutrients and was exposed to strong winds. With equivalent rate of growth, some of the spruces in the clumps in Big Glade 8 and 10 inches in diameter would be 125 years or more in age.

Only a few spruce seedlings are encountered in the open glade, showing that establishment there is very difficult (fig. 17). The migration is chiefly from the west, in the direction of the prevailing winds, which carry the seeds. The recently uprooted spruces in the glades, the trunks now being covered with mosses and lichens, and the countless trunks encountered at all depths to 13 feet in the borings, all attest the attempts at invasion of this area for hundreds of years, perhaps thousands, and the magnitude of the casualty list.

Discussion

The present study has revealed much about the origin of the level area and the origin of the bog conditions, yet there are many questions unanswerable relative to past history and age. It is very difficult to estimate the length of time represented by the 15 feet of sediments which have been studied. They are certainly of Quaternary origin. They probably represent the later part of the glacial and post-glacial periods.

The pollen diagram shows that spruce and fir were dominant regionally at the time of the accumulation of the 13½-foot level of marl (fig. 13). This might seem at first to make the bog comparable in age with the Ohio and Indiana bogs, which are estimated at 30,000 or more years (6), and showing the same forest sequences mentioned by SEARS (9). The 13½-foot level would thus represent the cool-moist or spruce-fir period; the 11-12½-foot levels, the warmer and drier or pine period, etc. The altitude here is 2800-4000 feet higher than at the Indiana and Ohio bogs, however, and the

spruce-fir dominance undoubtedly persisted longer. The time since spruce-fir dominance in those areas has been estimated at about 10,000 years (8). The rate of peat formation has been the basis for this estimation (10). In the area of this study the rate of peat formation has probably been slower than in the other bogs mentioned because of lower temperature and differences in origin and continuation of bog development.

The clays and marl probably were deposited in the later glacial period, and perhaps a part of the algal ooze was formed then—or in the early post-glacial period while it was yet too cool for many aquatic seed plants. Most of the peat probably was formed in the post-glacial period.

When the depressions were first formed by the levee building of the streams, water accumulated, especially in the Big Glade area. For a long period it was too cold for much plant life, so that clays and marls and later algal ooze accumulated; then, as the climate became warmer, increased plant life filled the water and initiated the sedge swamp, which formed the 5 feet of sedge peat now overlying the 4 feet of algal ooze and sedimentary peat. Some shrubs were scattered through the sedge (*Hypericum densiflorum*, for example), remains of which are now found in the sedge peat. The sedge community later retrograded to sphagnum over most of the glade area. Sphagnum has recently been giving way to *Polytrichum* in the more raised and better drained parts.

Trees have grown in the bog area since the sedge swamp was initiated and probably for some time before. Logs of spruce and hemlock are encountered to the bottom of the peat. Those in sedimentary peat or algal ooze could have been washed in by stream overflow. No logs have been encountered below the 13-

foot level. Shrubs have probably been growing along the streams since the time of deposit of the 13-foot level of sediments.

The future of the area with its successions and time required is as difficult to surmise as is its past. Succession is taking place, as shown by observations over the last 10 years. Shrubs are encroaching upon the moss-lichen, the sphagnum-cranberry-beaked rush, and the sedge-sphagnum communities. Trees are encroaching upon the shrub and other communities. Where shrubs or trees persist, their leaves and needles accumulate to raise the level higher above the water table and the acid substratum. At present, where a spruce or a clump of spruces have established themselves, many shrubs—such as *Menziesia pilosa*, *Viburnum cassinoides*, *Pyrus melanocarpa*, and *Gaultheria procumbens*—are thriving and spreading out from this area into the moss-lichen community.

In 1934 stakes were set up at a number of places on the border of different zones where encroachment seemed probable. During the succeeding 8 years *Gaultheria procumbens* has spread 10 feet in all directions from a clump of spruces into the *Polytrichum-Cladonia* association, or $1\frac{1}{2}$ feet per year. *Pyrus melanocarpa* advanced 25 feet, or 3 feet per year, into the same association. *Hypericum densiflorum* advanced 17 feet from the shrub belt on Cranberry River at transect B into the moss-lichen community. An old settler, who had often visited the area years ago but not in the last 20 years, stated that 30 years ago there were no shrubs in the Big Glade but only moss-lichen "tundra" with cotton grass and beaked rush. He was much surprised in 1941 to see the encroachment by shrubs from all sides. *Pyrus melanocarpa* is making more headway than any of the other shrubs. It has an underground

rootstock which grows rapidly under or through the moss layer and sends up new shoots. Yet its roots cannot penetrate the peat and it depends upon the moss for anchorage. It will not be able to survive without the moss until the soil has been built up by the decay of leaves and other plant parts, or better drainage is otherwise provided.

At another staked area, *Carex rostrata* advanced upon a sphagnum-cranberry-beaked rush community about 15 feet during the 8 years. The sedge has underground rootstocks which provide a good mechanism of encroachment similar to that of *Pyrus melanocarpa* and *Gaultheria procumbens*. Sphagnum spread several feet into a pure *Carex rostrata* community and an *Alnus-Viburnum* community. It can spread rapidly owing to its ability to absorb water and minerals through any part and to propagate vegetatively from many of its parts.

The bog forest is encroaching on every side of the area, but mostly on the west, the direction of the prevailing winds. Dispersal of conifer seeds should be greater from the west, and the young trees are better protected from excessive evaporation and uprooting.

It is only a question of time until the shrubs will cover the whole 600 acres, gradually to be replaced by bog forest. Once it is established, it should remain as an edaphic climax, until the streams are entrenched so that the peat can be eroded and provide a drained soil for the regional climax forest. The rate of downward cutting of the streams is greatly increasing, owing to the fact that Cranberry River, which has been cutting in the hard Princeton conglomerate below the bogs, is now cutting in the soft Hinton strata. The new course of the river along the north side of Big Glade is evidence that entrenchment and peat erosion are now occurring.

Summary

1. The Cranberry Glades area in West Virginia comprises about 600 acres of apparently level land covered with bog forest, shrub, and areas of sedges, mosses, and lichens, commonly called "glade." Most of the area is underlain by peat or organic material from a few inches to 11 feet in thickness.

2. The level area, upon which 15 feet of inorganic material and peat have accumulated, represents a part of the Harrisburg peneplain temporarily base-leveled in the soft shales and sandstones of dipping strata.

3. Bog conditions were initiated by the deposition of levees along the banks of streams, causing undrained conditions in the areas away from the streams. This change from degrading to aggrading action probably occurred during glacial time, when the streams, swollen by increased precipitation and decreased evaporation and overloaded with sediments from slopes unprotected by sufficient vegetation cover, deposited their sediments over the area. In post-glacial time the streams with reduced volume of water slowly built their levees higher during floods, causing further damming and further peat accumulation.

4. Six plant communities are differentiated: sedge-sphagnum, sphagnum-cranberry-beaked rush, moss-lichen, bog forest, and two shrub communities.

5. The structure and pollen of the transect profiles of the sediments and the existing communities point to succession from shallow water, with its accompanying communities, to a sedge swamp, to a retrogression to sphagnum, to moss-lichen in some parts, to shrub, to bog forest.

6. Succession will continue until bog forest has occupied the whole area, to be followed by regional climax forest only

when sufficient stream erosion has removed the peat accumulation and provided sufficient drainage.

The writer greatly appreciates the helpful direction and encouragement given by Dr. CHARLES E. OLMSTED, University of Chicago, under whose supervision the work was done. Sincere thanks are also expressed to Dr. P. D. STRAUSBAUGH who suggested the problem for study; to Dr. G. D. FULLER who offered many suggestions and help on the problem; to Dr. DAVID KIRBY who accompanied the writer into the bogs several times and gave assistance in the study; to Dr. P. B. SEARS who made the pollen analysis; to Dr. E. L. CORE who identified several sedges; and to Dr. L. E. ANDERSON who identified some of the mosses and lichens.

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